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A Multiple Criteria Evaluation of a New Streets Development Projects in Vilnius City

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Abstract. The paper considers the technological development of a new streets equipment in Vilnius street network. All main transport infrastructure projects in Vilnius city are presented and analyzed with reference to the selected system of transport projects assessment criteria. This article describes the situation and progress of the main streets development projects in Vilnius and shows the influence for whole Vilnius city transportation system. The paper also analyses parameters for infrastructure projects for the multiple attribute ranking of a new streets development or reconstruction in Vilnius city. Multi-criteria methods have been chosen to rank three projects and to estimate the best and most effective transport network object based on the preferred technological, transportation operational and financial data. The experts of different decision-making groups have analyzed the importance of parameters selected for assessing alternatives of a new Vilnius city streets development projects ranking. The experts on the transport system have been invited to determine the relative weights of the defined criteria. Two techniques, including*, SAW (Simple Additive Weighting)* and *TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)* methods have been used and compared to determine the most efficient project based on economic and technological parameters. To rank alternatives and to make a comparison of the obtained calculation results, two multi-criteria methods have been applied in this research.

Keywords: multicriteria analysis, transportation, SAW, TOPSIS, streets development projects.

Conference topic: Sustainable urban development.

Introduction

Motorized mobility has increased in a significant way in last years, and this has brought too much congestion in urban areas. This situation needs for investment in transport infrastructure and needs effective assessment of transport infrastructure projects. Therefore, urban areas need effective and flexible transport systems in order to develop policies integrating the three aspects of sustainability: economy, society and environmental. Changes in transport system and transport infrastructure development scenarios assessment could be based on economic, social and environmental principles (Susnienė 2012; Joumard, Nicolas 2010; Kavaliauskas 2008). Other scientists describe the transport system development assessment based on traffic modelling and traffic parameters (López-Neri *et al.* 2010; Fernández 2010).

To quantify the progress towards the objectives of sustainable transportation, it is crucial to define the proper indicators (Hueting, Reijnders 2004).While there are no well-defined selection rules to identify the appropriate indicator sets associated with the specified sustainability objectives, there are several such lists of indicators proposed in the literature (Dobranskyte-Niskota *et al.* 2007; Bickel *et al.* 2003; Litman 2008; Malekpour *et al.* 2017). It can be argued that sets constructed according to the available data and of smaller sizes are more convenient to use but may fail to include important impacts. In contrast, larger sets can be more comprehensive but the costs associated with the data collection process can be prohibitive (Litman, Burwell 2006). There are also additional dimensions mentioned in some studies such as technical, operational or institutional (Jeon *et al.* 2010).

Vilnius City Municipality considers or perform development of transport infrastructure projects related with new street construction or present streets reconstruction. This research performs different-scenarios multiple criteria assessment of a new arterial streets development projects based on social and economic data. There were evaluated tree main new streets development projects in Vilnius city according Vilnius city comprehensive plan: 1) The third stage of Vilnius western bypass; 2) Siaurine street; 3) Mykolo Lietuvio street. This research performs ranking assessment of these new three transport infrastructure projects by SAW and TOPSIS multiple criteria methods based on social and economic criterions.

Multiple criteria methods are used for the assessment of public transport system and different public transport subsystems (Achillas *et al.* 2011). Also, they could be used in assessing different transport infrastructure projects (Salling, Banister 2009; Polydoropoulou, Roumboutsos 2009). There is a wide range of methods based on multiple criteria utility theory: SAW – Simple Additive Weighting (Ginevičius *et al.* 2008; Sivilevičius *et al.* 2008; Jakimavičius *et al.* 2016); TOPSIS – Technique for Order Preference by Similarity to Ideal Solution (Zavadskas *et al.* 2006);

COPRAS – Complex Proportional Assessment (Zavadskas *et al.* 2006); AHP – Analytic Hierarchy Process (Sivilevičius 2011b; Maskeliūnaitė, Sivilevičius 2012; Wu *et at.* 2008; Aghdaie *et al.* 2012; Isik, Aladag 2016).

The main aim of this work is to involve multiple criteria methods in the assessment and analysis of different transportation infrastructure projects and to carry out this type of analysis for the Vilnius city a new streets development projects priority ranking and evaluation.

Transportation system data in Vilnius city

The existing Vilnius city street occupancy and public transport flows straight belongs from citizen's number. Vilnius is a growing city and each year this number increases (see Table 1)

Table 1. Population comparing Lithuania and Vilnius city

Year	Population in Lithuania	Population in Vilnius city	Vilnius city population in percentages from Lithuania – %	Vilnius district population	Sum of Vilnius city and Vilnius district population
2010	3329.0	**560.2**	16.8	96.5	656.7
2016	2888.6	**543.5**	**18.8**	95.2	638.7
Change 2016–1980	0.84	1.08	1.29	1.03	1.07
Change 2016–2000	0.78	0.94	1.21	1.06	0.96

The number of vehicles in Vilnius City grows by about 3% per year. The number of private cars in Vilnius increased from 265 cars per 1000 inhabitants in 1999 up to 580 in 2011. A sharp bounce of motorization level invokes a lot of transportation problems (Jakimavičius, Burinskienė 2007). In 2008–2011 saturation was reached. In comparing with other Europe cities number of vehicles in Vilnius city is high.

The number of vehicles per 100 inhabitants in Vilnius city are the biggest among other cities in Lithuania and this number is bigger than in other European cities as well. The number of vehicles per 100 inhabitants in Vilnius is 1.06 time bigger that it is an average in Lithuania. Total number of automobiles in Vilnius takes 18 percentages of whole Lithuanian automobiles number. Modal split of Vilnius city transport modes is presented in Table 2.

Table 2. A modal split of trips in Vilnius City

Trip mode	1980	1993	2006	2011	2011/ 1980
On foot	44.1	38.0	34.5	35.5	0.80
By public transport	47.1	49.4	33.1	24.6	0.52
By taxi	2.9	0.1	0.4	0.7	0.2
By train	0.3	0.1	0.4	0.1	0.3
By bicycle	0.1	0.2	0.4	0.6	6.0
By car	5.5	12.2	31.2	38.5	7.0

Many scientific researches analyses transport system from the point of modal split of citizen trips (Bharat, Odd 2011). These tendencies show that the use of public transport in Vilnius is rapidly decreasing due to the growth of motorization level and unattractiveness of public transport.

Vilnius city has these main streets which a full filled by motorized transport. This main Vilnius city streets network arterials are presented in Table 3.

Table 3. Traffic volumes in Vilnius main streets

Street name	Street section		Length of street section	Traffic in morning rush hours (veh./hour)		2006–2011 percentage change	Anual traffic increation in %
	From street	To street		2006	2011		
Kareiviu str.	Zirmunu str.	Verkiu str.	603	1800	2100	16.70%	3.90%
Ozo str.	Kalvariju str.	Gelezinio Vilko str.	1112	3150	3960	25.70%	5.90%
Buivydiskiu str.	Ozo str.	Ciobiskio str.	743	1700	2125	25.00%	5.70%
Laisves str.	Buivydiskiu str.	Siaurine str.	571	2280	3320	45.60%	9.90%
Ukmerges str.	Ozo str.	Fabijoniskiu str.	1132	3600	5310	47.50%	10.20%
Gelezinio Vilko str.	Ozo str.	J.Kazlausko str.	946	2570	3930	52.90%	11.20%
Kalvariju str.	Ozo str.	Zvalgu str.	818	2110	2420	14.70%	3.50%
Ateities str.	Ukmerges str.	Fabijoniskiu str.	429	1220	2720	123.00%	22.20%

Traffic flow analysis in the main Vilnius city arterial streets points that Vilnius city needs new streets and bypasses. So according Vilnius city comprehensive plan are planned to build Vilnius city western bypass, to do reconstruction of Mykolo Lietuvio street and to build new Siaurine street. This research performs multicriteria ranking of these 3 projects based on social and economic aspects.

Methodology

Social and economic indicators data for Vilnius new streets development projects evaluation were obtained from Vilnius city general plan and Vilnius city transportation strategy and different transportation projects documentation. Indicator system with indicators values have been taken as input data for a multiple criteria assessment of different transportation development projects from the point of transport system economic and social aspects.

Indicators

In order to perform the assessment of three Vilnius city streets development projects scenarios based on multiple criteria methods it is necessary to create indicators system. An indicator is a quantitative or qualitative parameter that can be assessed in relation with a criterion. Also, an indicator could be measured, estimated and evaluated. Below the possible indicators are listed for a new streets development projects ranking in Vilnius city:

- Project development price (mln. eur.);
- Average taken traffic flow from other neighborhood streets (1000 vehicles/hour);
- Average taken transit traffic flow (flow between roads outside the city and flow between different zones in a city) (%);
- Average population in intersected transportation zones (1000 inhabitants);
- Average working places in intersected transportation zones (1000 inhabitants).

The present transport model of Vilnius City was used and three new transportation projects in Vilnius city have been ranked according multicriteria methods. The calculated values of indicators are the main parameters for transportation projects priority assessment from the economic and social view.

Transportation projects for assessment

The research analyses and ranks alternatives of new Vilnius city transportation projects development. Below the alternatives which were evaluated and ranked based on SAW and TOPSIS methods are described (Zavadskas *et al.* 2001).

Project No. 1 represents development the last stage of the western Vilnius city bypass. Analyzed the third stage of Vilnius city western bypass goes from Sesiuoliu str. till Ukmerges str. Total length is about 5 km. This street has 4 projected driving lines and green line (3m). Technical parameters of carriageway are (4x3.75+2x2.75+0.5x2+0.25x2) – total 22.0m. Bicycle paths and public transport infrastructure are not planned. Crossing are multilevel. Projected this street should be A1 category. This project finishes the western Vilnius city bypass and allows to go traffic from two Lithuanian main roads A1 (Kaunas direction) and A2 (Panevezys direction). This project is presented in schema bellow (see Fig.1 a).

Project No. 2 represents of new Siaurine street development which will intersect half of Vilnius city. According the project this street goes from the western Vilnius city bypass till Zirmunu str. Total length is 6.5 km. This street would have 6 driving lines, 2 of them would be dedicated for public transport. The width of this street would be 40–70m. This street would intersect these streets: Kalvariju, Gelezinio Vilko, Ukmerges, Justiniskiu and Laisves. Siaurine str. Projected this street should be B1 category and would have pedestrians and bicycle paths. According the project this street would have 6 multilevel crossings. This project is presented in schema (see Fig.1 b).

Project No. 3. represents of reconstruction of Mykolo Lietuvio street which is located in north part of Vilnius city. According the project this street goes from Ukmerges str. till Mokslininku str. Total length is 2.7 km. This street should be B1 category, would have 4 driving lines, green line, lightning and public transport infrastructure, 2.5m width bicycle paths. In 2015 average traffic flow in Mykolo Lietuvo str. was 1380 vehicles per day, according prognosis in 2025 this number should be 23100 and 0.5 percentage of this number be heavy transport. This street will represent Vilnius city northern bypass and allows to go traffic from two Lithuanian main roads A2 (Panevezys direction) and A14 (Utena direction). This project is presented in schema (see Fig. 1 c).

Fig. 1. Illustration transportation projects in Vilnius city: (a) the third stage of Vilnius city western bypass fields; (b) Siaurine street; (c) reconstruction of Mykolo Lietuvio street

Assessment of indicators importance

The importance of each indicator was estimated by questioning 20 experts of transportation system. Table 4 shows the results of experts questioning. The lowest value means that the indicator is the most important; the highest value means that the indicator is less important (Zavadskas *et al.* 2001).

Table 4. Results (ranks) of experts questioning

Experts			Indicators		
	R1	R2	R3	R4	R5
E1	1	2	3	5	4
E2	1	2	3	4	5
…	...	...	...	...	...
t_{sum}	26	41	62	81	92
t_{avg}	1.3	2.05	3.1	4.05	4.6

$$t_{sum}=302; \quad t_{avg}=15.1$$

Below the calculations of indicators importance are presented (Table 5).

Table 5. Results of subjective indicators importance (weights)

$\underline{q}_i=1-g_i$	$g_i = \dfrac{t_{avg,i}}{\sum_{i=1}^{n} t_{avg,i}}$	Importance / weights (q_i)
$\underline{q}_1 = 0.914$	$g_1 = 0.086$	$q_1 = 0.229$
$\underline{q}_2 = 0.865$	$g_2 = 0.135$	$q_2 = 0.216$
$\underline{q}_3 = 0.795$	$g_3 = 0.205$	$q_3 = 0.199$
$\underline{q}_4 = 0.733$	$g_4 = 0.267$	$q_4 = 0.183$
$\underline{q}_5 = 0.696$	$g_5 = 0.304$	$q_5 = 0.174$

The weights could be also estimated based on a more sensitive methodology (Sivilevičius 2011a). Calculation of indicators set of sum-square:

$$S = \sum_{i=1}^{n} \Big(\sum_{j=1}^{l} t_{ij} - \frac{1}{n} \times \sum_{i=1}^{n} \sum_{j=1}^{l} t_{ij} \Big)^2; \tag{1}$$

$$\frac{1}{5} \sum_{i=1}^{5} \sum_{j=1} t_{ij} = 60.4; \quad S = \sum_{i=1}^{5} \Big(\sum_{j=1}^{20} t_{ij} - 60.4 \Big)^2 = 2985.2,$$

where: S – results of criterions valuation deviation of sum-square; t_{ij}– experts j valuating rank for i-th criterion; l – number of experts; n – number of indicators in indicators set.

1) Estimation of the coefficient of concordance:

$$W = \frac{12 \times S}{l^2 (n^3 - n)} = 0.746. \tag{2}$$

2) Calculation of actual chi-square (χ^2):

$$\chi^2 = \frac{12 \times S}{l \times n(n+1)} = 59.70. \tag{3}$$

Validation results of experts questioning:

a) $W>0$, $W=0.746>0$;
b) $\chi^2 > \chi^2_{TABLE}$, 59.70>13.28.

($\chi^2_{TABLE} = 13.28$, when the variance is $v = n - 1 = 5 - 1 = 4$ and significance level $\alpha = 0.01$).

Validation results show that the experts' opinions are compatible. Below are shown criterions with their numerical values and calculated importance (Table 6).

Table 6. Modelling results of project assessment indicator weights

No	Indicator	Project No			Importance / weights (q)	Function
		1	2	3		
R1	Project development price (mln. eur.)	100	80	29	0.229	min
R2	Average taken traffic flow from other neighborhood streets (1000 vehicles/hour)	3	2.5	2	0.216	max
R3	Average taken transit traffic flow (flow between roads outside the city and flow between different zones in a city) (%)	20	10	15	0.199	max
R4	Average population in intersected transportation zones (1000 inhabitants)	97.5	169.5	21.7	0.183	max
R5	Average working places in intersected transportation zones (1000 inhabitants)	38.5	21.4	14.6	0.174	max

Project assessment approaches

The methods SAW and TOPSIS have been used for ranking transport infrastructure projects. The transport infrastructure projects ranking was performed based on the SAW method. Table 7 shows the normalized indicators matrix calculated by SAW method.

Table 7. Normalized indicators matrix for the SAW calculation

	Normalized indicators for the SAW method				
Alternative	R1	R2	R3	R4	R5
Project No. 1	0.290	1.000	1.000	0.575	1.000
Project No. 2	0.363	0.833	0.500	1.000	0.556
Project No. 3	1.000	0.667	0.750	0.128	0.379

Having normalized the matrix each indicator of a concrete transport infrastructure project is multiplied by its importance. The multiplied indicators are summed up for each row (for each evaluating project). The largest value means the highest rank for transport infrastructure project assessment. Results by SAW assigns the highest rank to Project No. 1 and the least rank takes Project No. 3.

Also scenarios ranking have been evaluated based on the TOPSIS method. According to the Topsis method the indicators matrix was normalized (see Table 8).

Table 8. Normalized indicators matrix for TOPSIS calculation

	Normalized indicators for the TOPSIS method				
Alternative	R1	R2	R3	R4	R5
Project No. 1	0.762	0.684	0.743	0.496	0.830
Project No. 2	0.609	0.570	0.371	0.862	0.461
Project No. 3	0.221	0.456	0.557	0.110	0.315

Normalized matrix is used for calculating the ideal positive (f_j^+) and negative (f_j^-) variants;

$$f_j^+ = \{0.051; 0.148; 0.148; 0.158; 0.144\}; \quad f_j^- = \{0.174; 0.098; 0.074; 0.020; 0.055\}.$$

Calculation results for all variant deviation from the negative and positive variants are presented in Table 9.

Table 9. Calculation results of TOPSIS variants deviation

	Alternative		
	Project No. 1	Project No. 2	Project No. 3
D_i^*	0.140	0.134	0.175
D_i^-	0.145	0.146	0.129

$$C_{PR1}^* = \frac{0.145}{0.140 + 0.145} = 0.507; \quad C_{PR2}^* = \frac{0.146}{0.134 + 0.146} = 0.522; \quad C_{PR3}^* = \frac{0.129}{0.175 + 0.129} = 0.424.$$

Calculation results and discussion

The multi-criteria methods showed the similar results of transport infrastructure projects (alternatives) ranking. The most attractive alternatives are Project No. 1 and Project No.2. According multicriteria methods rank of Project No. 3 is less attractive (see Table 10).

A multiple criteria research of Vilnius city transport infrastructure projects assessment showed that project development price is not the main factor for assessment. Transport infrastructure project rank belongs from project operation effectiveness to whole transport system, how developed project makes influence for traffic flow reduction from other neighborhood streets, how new street unload transit traffic from main Vilnius city streets. Also important factor is transport infrastructure project development place in a city, how many inhabitants and working places will serve this new developed transport infrastructure.

Table 10. Results of multiple criteria evaluation using SAW and TOPSIS methods

Transport infrastructure project		Project No. 1	Project No. 2	Project No. 3
SAW	S_j	0.761	0.642	0.612
	No.	1	2	3
TOPSIS	C_j^*	0.507	0.522	0.424
	No.	2	1	3
Cumulative rank		3	3	6
Rank		1-2	1-2	3

Two multicriteria methods showed different ranking of the best project alternative. Analysis by SAW method gave the best project alternative to the 3rd stage of western Vilnius by pass, otherwise analysis by TOPSIS Siaurine str. ranked in the first place. From the transportation point of view these two projects are very important to whole Vilnius city transportation system and for mobility between different transportation zones in a city. From the point of connectivity Siaurine street has the biggest population and working places numbers in intersecting transportation zones. This street connects transportation zones with population about 170 thousands and 22 thousand of working places. From the point of traffic and transit traffic reduction form neighborhood streets the 3rd stage of the western Vilnius by pass has the biggest numbers from all evaluated projects. This bypass will take about 3 thousand vehicles per hour traffic flow from other streets and will unload about 20 % of transit traffic form other main Vilnius streets. A multiple criteria analysis showed that these two streets are very important for Vilnius city transport system and will make big positive changes in Vilnius transport system operation. Less important is Mykolo Lietuvio street reconstruction, but also this project will change transport system operation especially in neighborhood transportation zones, also will unload about 15 % of transit traffic.

Conclusions

1. The analysis of Vilnius City a new streets development projects assessment has shown that the multiple criteria methods are suitable for the assessment of transport system development projects. The multiple criteria methods could be successfully used in the general and strategic planning processes. Also these methods could be used for other transport infrastructure projects development priorities.
2. The multiple criteria methods are flexible and could be successfully used for decision makers form municipality in order to perform transport infrastructure projects development priorities. A multiple criteria analysis can ensure a fair and transparent decision-making process. So this analysis is impartial and independent of the level of an individual decision-maker's political influence.
3. The future research of Vilnius City transportation infrastructure projects assessment could take into account not only the indicators which present the financial and traffic condition data. It could also involve the indicators from the social, safety and environmental groups in order to carry out a more complete assessment. In addition, created new indicators set and used in this research multicriteria method caould be adopted in other municipalities in order to perform for a new streets development projects evaluation and other transport infrastructure projects assessment.
4. Multicriteria assessment showed that the highest evaluated rank has a project of Vilnius city the western bypass. This could be explained that this project dominates in transit traffic reduction form neighborhood streets. This bypass will take about 3000 vehicles per hour traffic flow from other streets and will unload about 20 % of transit traffic form other main Vilnius streets.

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